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RADON DAUGHTER MEASUREMENTS WITH A DISCRETE, MICROPROCESSOR-CONTROLLED, GRAB-SAMPLER

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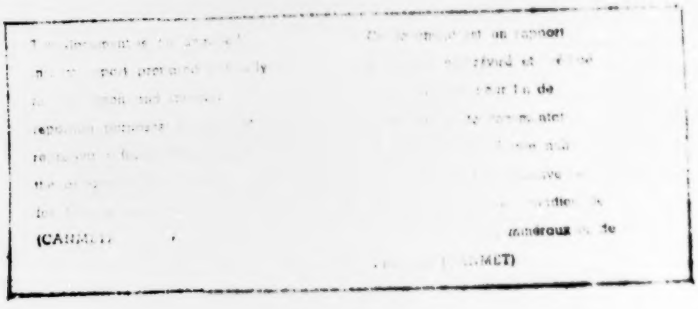

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RADON DAUGHTER MEASUREMENTS WITH A DISCRETE, MICROPROCESSOR-CONTROLLED, GRAB-SAMPLER

by

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ABSTRACT

A discrete, microprocessor-controlled, radon daughter grab-sampler manufactured by Harshaw (U.S.A.) has been evaluated. Measurements were carried out under laboratory controlled conditions in a large 'radon room'. Data obtained with the Harshaw instrument have been compared with conventional grab-sampling by the Markov method and by an automated grab-sampler, Pylon WL-1000C, and a radon daughter monitor operating on time integrating principles, EDA WLM-300. Tests were done under slow- and fast-fluctuating radiation conditions in order to determine the response of the above instruments for these two cases of practical interest. A number of suggestions are made to further improve the performance of the instrument, such as relocating the sampling head and connecting cable to prevent contamination, tampering or accidental damage. Reduced weight and size would be beneficial. Changes in hardware and software could be made to increase versatility.

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INTRODUCTION

Routine monitoring of radiation levels in underground and surface environments helps to prevent unnecessary health risks to occupational workers. α-radiation and γ-radiation monitoring is common in uranium mines and the uranium milling industry. However, unless high grade ores are mined and processed, only α-radiation is usually considered. The α-radiation variable of interest is in most cases the Working Level (WL), a measure of the α-energy emitted by the radon gas progeny.

Radiation monitoring is essentially of two kinds: grab-sampling and continuous monitoring. In the grab-sampling method an air sample is taken and the radiation level is determined. Most of the experimental methods that have been developed for the determination of the WL involve the measurement of α-particles from either RaA or RaC' or both (1-8). However, techniques based on β-particle count have also been investigated and applied (9-12). Relatively simple techniques involving a single total α- or β-count are commonly used when the only radiation variable of interest is the WL (1-5,10,11). Other more sophisticated techniques based on several α-counts enable the calculation of the radon daughters concentrations in addition to the WL(7,8).

The Kusnetz (2,3), Markov (1) and Rolle (4,5) methods, based on a single total α-count, and the β-particle method, e.g., (10), based on a single total β-count, permit a simple determination of the WL. A more accurate determination of the WL, in addition to the calculation of the concentration of the radon decay products, is possible if use is made of other more sophisticated techniques, such as the Tsivoglou method (7), the Thomas method (8) or some α-spectrometric methods (13,14,15). Furthermore, instrumentation and concepts have been developed that allow the determination of the WL to be made in a matter of a few minutes. The instruments are commonly known as

Instant Working Level Meters (IWLM). Evans and Schroeder (16) and later Groer (17), Rolle (18), Hill (19) and James and Strong (20) must be credited with the early development of the concept and/or basic instrumentation that has led to the design of several IWLM prototypes. A summary of radiation instrumentation has been given by Bigu elsewhere (21).

The need for a simple, fast and reliable method for the routine determination of the radon daughter concentration and Working Level, WL(Rn), by a small-sized, automated, instrument capable of performing the sampling, counting and raw data processing operations with minimum attendance has been felt for some time. In addition, it would be highly desirable for the instrument to be light, electronically reliable, rugged and dust- and moisture-proof as its use is intended for harsh environmental conditions.

Harshaw (U.S.A.) has developed a microprocessor-controlled Working Level monitor capable of determining the concentration and Working Level of the radon progeny by automatic, programmable, grab-sampling means. The instrument is commercially available under the name Radon Daughter Analyzer. It consists of a Radon Daughter Detector, Model 101, and Radiation Computer, Model 100. For simplicity the system will be referred to hereafter as the Harshaw-WLM, where WLM stands for Working Level Meter. The WLM is based on instrumentation and analytical procedures developed at the Argonne National Laboratory by Groer et al. (17,23) who designed an earlier prototype known as the Remote Working Level Meter (RWLM).

This report presents experimental data obtained with the Harshaw-WLM in a radon/thoron calibration facility. Measurements were compared with conventional grab-sampling methods and with two other recently developed instruments: an automated grab-sampler developed by Pylon Instruments, Ottawa, under the commercial name WL-1000C and a continuous Working Level monitor

developed by EDA Instruments, Toronto, Model WLM-300. Measurements, not reported here, were also conducted at a uranium mine tailings site in the Elliot Lake area.

DESCRIPTION OF THE APPARATUS

The Harshaw Radon Daughter Analyzer (WLM) measures the concentration and Working Level of radon daughter decay products. It presents the data in printed form as well as on a digital Liquid Crystal Display (LCD) read out. The WLM consists of two portable instruments, a Radon Daughter Detector, Model 101, and a Radiation Computer, Model 100. Both instruments are ruggedly constructed for field use.

The Radon Daughter Detector contains a Harshaw diffused-junction (DJ) α-detector, a Harshaw CaF_2 β-detector, charge sensitive pre-amplifiers and a high voltage power supply. In addition, the Radon Daughter Detector contains an automatic filter paper transport sub-assembly and a high flow-rate sampling pump sub-assembly, the combination of which will be referred to as the sampling head. Filter paper 0.8 μm is used in the sampling head. The filter paper is advanced to the sample station where air is drawn through the filter paper at a given, programmable, rate for two minutes. (A nominal flow-rate of about 30 L/min is normally used.) At the end of the sampling period, the sample is automatically advanced and positioned between the α- and β-detectors.

Alpha particles are counted with the DJ detector having an active area of 700 mm^2. It is mounted at the air inlet side of the filter paper to minimize α-particle absorption and hence maximize α-counting efficiency. The DJ has a silicon surface 0.2 μm under a protective coating so that it can be cleaned without damage to the active surface area.

Beta particles are detected with the CaF_2 (Eu) thermoluminescent

crystal mounted on a quartz light pipe and optically coupled to a photomultiplier tube. The CaF_2 (Eu) crystal is about 5 cm in diameter and approximately 0.25 mm thick and is protected with a 0.025 mm thick aluminum window. The β-detector is mounted under the filter paper directly opposite the DJ. No appreciable absorption of β-particles takes place in the filter paper.

The Radiation Computer contains several printed circuit boards including a CMOS microprocessor, three single channel scalers, memory units, arithmetic processor and interface electronics as well as a 20-column thermal printer and a LCD read out. Two of the single channel scalers are used for α-spectroscopy. The third channel is used as a β-counter or scaler. The microprocessor is used to control the filter paper transport and to process the data collected from the scalers.

The following radiation variables of interest are calculated and printed: concentration of RaA, RaB and RaC and Working Level, i.e., [RaA], [RaB], [RaC] and WL(Rn), respectively. In the model tested, the concentrations were given in atoms/L.

The sampling flow-rate (L/min) and the frequency of sampling, i.e., inter-measurement delay interval, are programmable within certain limits. The maximum allowable delay is 218 min. Other functions are also variable and the instrument is quite versatile in a number of ways. The interested reader should refer to the instruction manual for further information. The total time taken for sampling and counting is slightly over 4 min: 2 min sampling time, 6 sec waiting time between sampling and counting and 2 min counting time. Once the instrument is started it will keep on sampling and counting until manually stopped.

EXPERIMENTAL PROCEDURE

The Harshaw WLM was tested in a large radon/thoron room designed for calibration purposes. Radon daughter concentration and Working Level were determined with the instrument and compared with an automated grab-sampler Pylon WL-1000C. In addition, the Working Level, as determined by the Harshaw-WLM, was compared with a continuous Working Level monitor EDA WLM-300 and with conventional grab-sampling by the Markov method, which also enabled [RaA] to be calculated.

Most of the tests were conducted under rapidly changing radiation conditions because this is a situation of considerable practical importance. However, due to the short sampling time of the Harshaw-WLM, i.e., 2 min, one may consider WL in the room to remain essentially constant during the sampling period. This was not strictly true for other instruments and methods which required 5 min sampling. The tests were conducted at a temperature and relative humidity ranging, respectively, from 19 to 24°C and 70 to 85%, approximately. Measurements under low and high aerosol concentration, i.e., 10^3 to 10^5 cm^{-3} approximately, were carried out with no appreciable difference indicating little plate-out of radon daughters in the sampling heads of the instruments used or on the walls of the room.

Some tests were also done in the field, particularly in a tailings pile. These tests, the results of which will be reported elsewhere, were mainly aimed at studying the response of the instrument under heavy fine tailings dust conditions.

Because of some practical difficulties which caused repeated delays by Harshaw in sending the instrument to the Elliot Lake Laboratory when special arrangements had been made for a thorough technical evaluation, the evaluation of the Harshaw-WLM as presented here should be considered far from

complete. Thus, more emphasis will be placed in ways to improve the performance of the instrument than in a strict data evaluation.

EXPERIMENTAL RESULTS AND DISCUSSION

Figures 1 and 2 summarize some of the data obtained with the Harshaw-WLM and by grab-sampling by the Markov method. Also shown are data obtained with an automated grab-sampler (Pylon WL-1000C) and a continuous monitor system (EDA WLM-300, Fig. 1). Figures 3 to 5 show the concentration of RaA, RaB and RaC, say [RaA], [RaB] and [RaC], respectively, as determined by the Harshaw-WLM and the WL-1000C, and [RaA] by the Markov method (Fig. 3).

Figures 1 to 2 show a series of experiments conducted at low and moderate radon daughter Working Levels, i.e., from 0.01 WL to about 1 WL. It can be seen that in general good qualitative agreement, i.e., WL-profile versus time is obtained with all the methods and instruments used. In quantitative terms, however, best agreement was found between the Harshaw-WLM and the WL-1000C. Measurements with the WL-1000C included the Rolle method and a short, programmable, version of an α-spectroscopy method (15). Measurements with the EDA WLM-300 (Fig 1) were done with an early sampling head design which exhibited plate-out problems (24,25). However, EDA Instruments has recently redesigned the sampling head and the results obtained have been found to agree quite well with grab-sampling data (26). (Notice that because of the time integrating nature of the instrument WL(Rn) data lag behind grab-sampling measurements by about 60 min.) In general, the Markov method gave significantly higher values for WL(Rn) than other methods and instruments used.

As with the tests corresponding to Fig. 1 and 2, good qualitative agreement was found for [RaA], [RaB] and [RaC] with the different methods and instruments used, although significant quantitative discrepancies were observed. Best data agreement was obtained for [RaB].

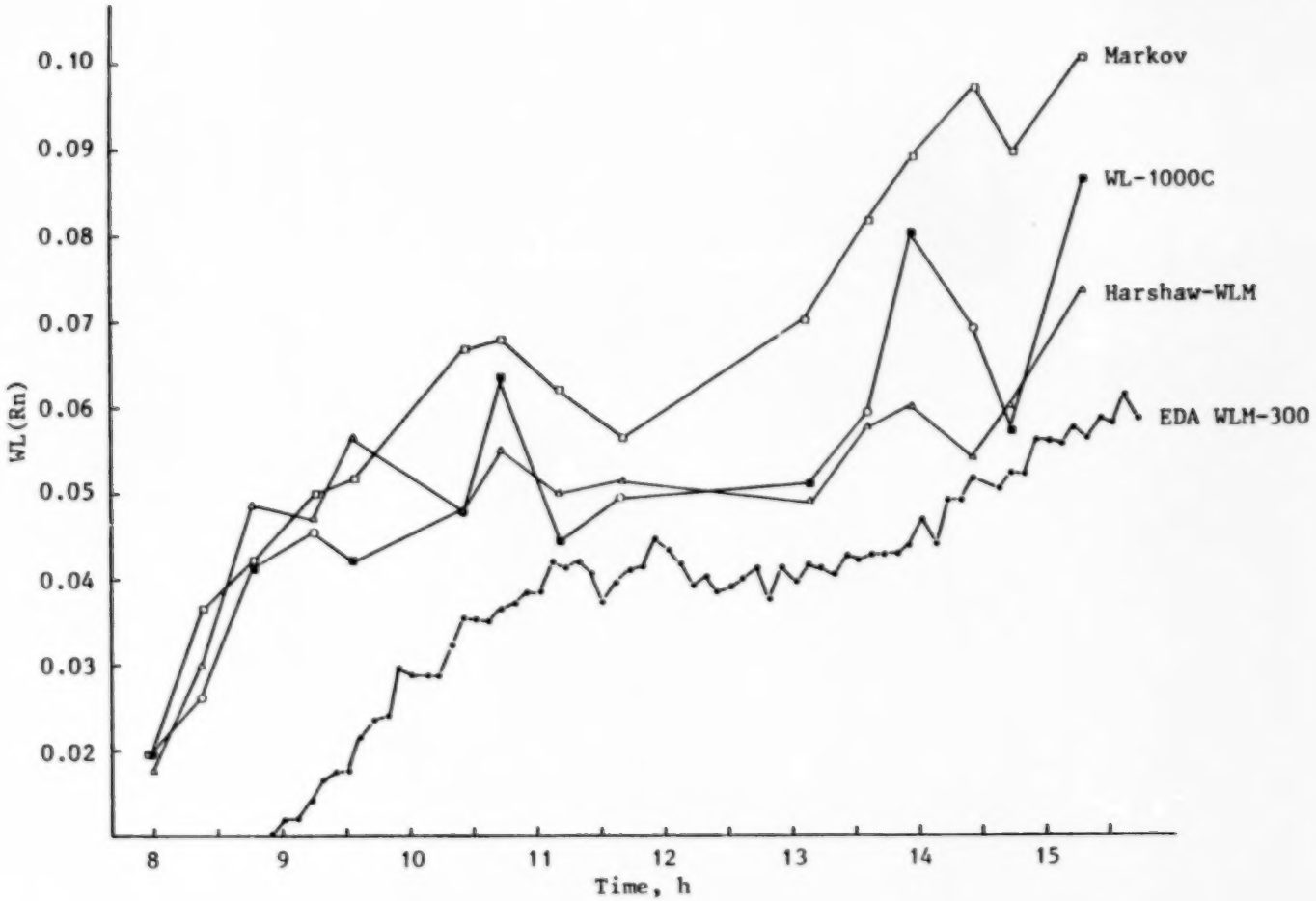

Fig. 1 - WL(Rn) versus time for the Harshaw-WLM and grab-sampling by the Markov method. Also shown are the results obtained with the WL-1000C (Rn α-spectroscopy, -■-, and Rolle, -O- methods) and the EDA WLM-300. Experiments were carried out in a radon room.

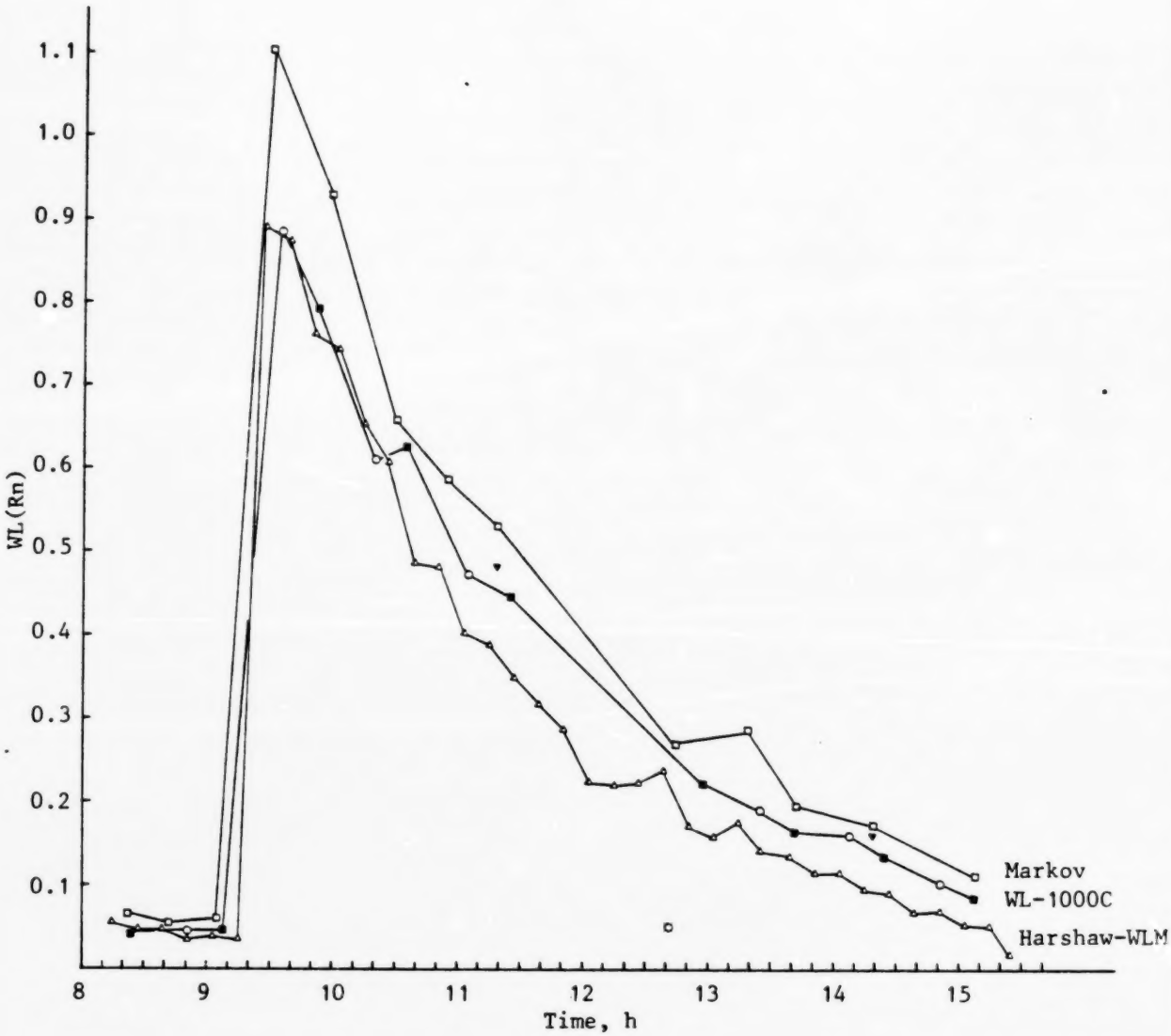

Fig. 2 - WL(Rn) versus time for the Harshaw-WLM and grab-sampling by the Markov method and the Kusnetz method (▲). Also shown are data obtained with the WL-1000C (Rn α-spectroscopy, -■-, and Rolle, -○-, methods). Experiments were carried out in a radon room.

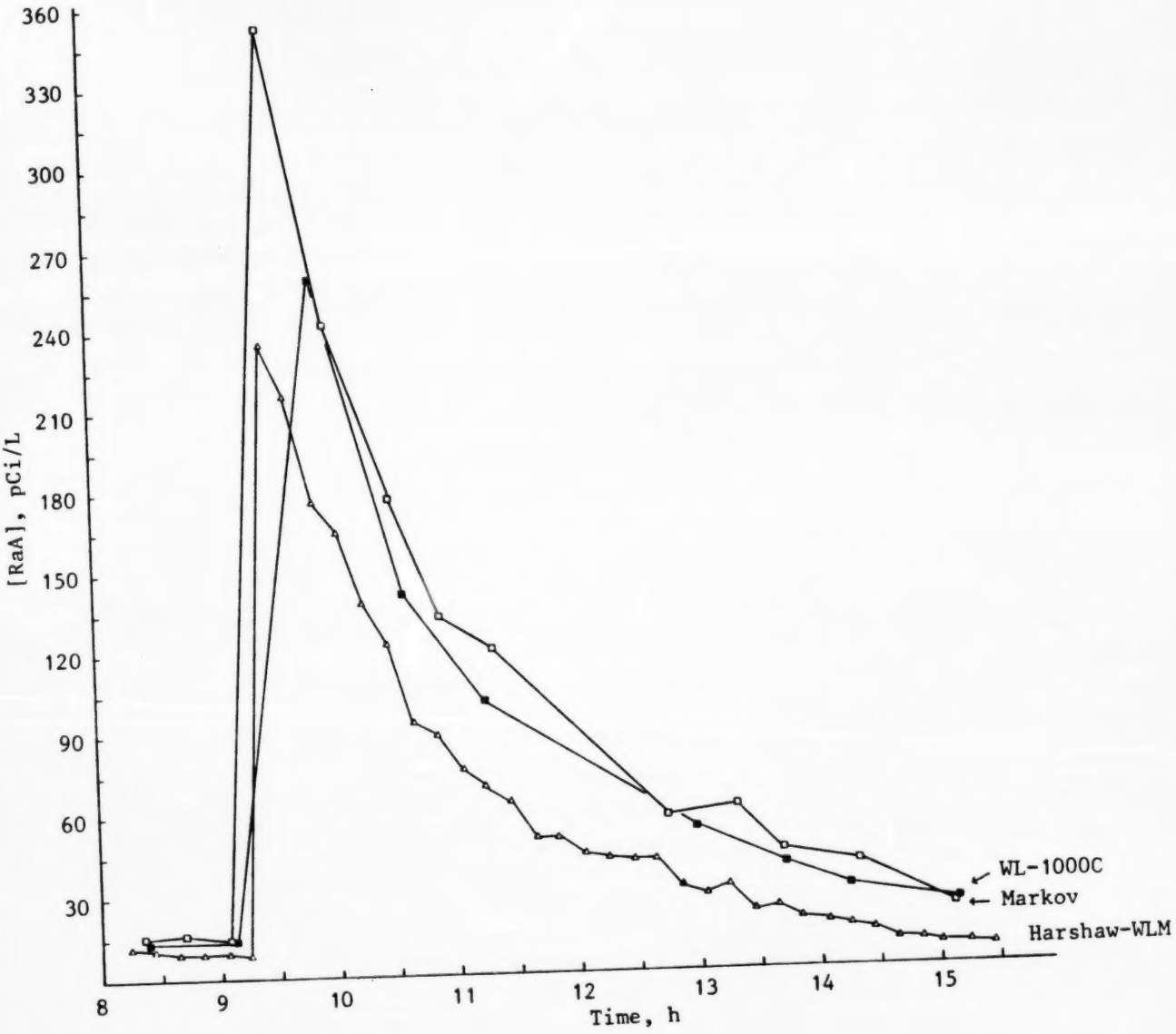

Fig. 3 - RaA concentration versus time for the Harshaw-WLM and grab-sampling by the Markov method. Also shown is [RaA] obtained with the WL-1000C (Rn α-spectroscopy). Experiments were carried out in a radon room.

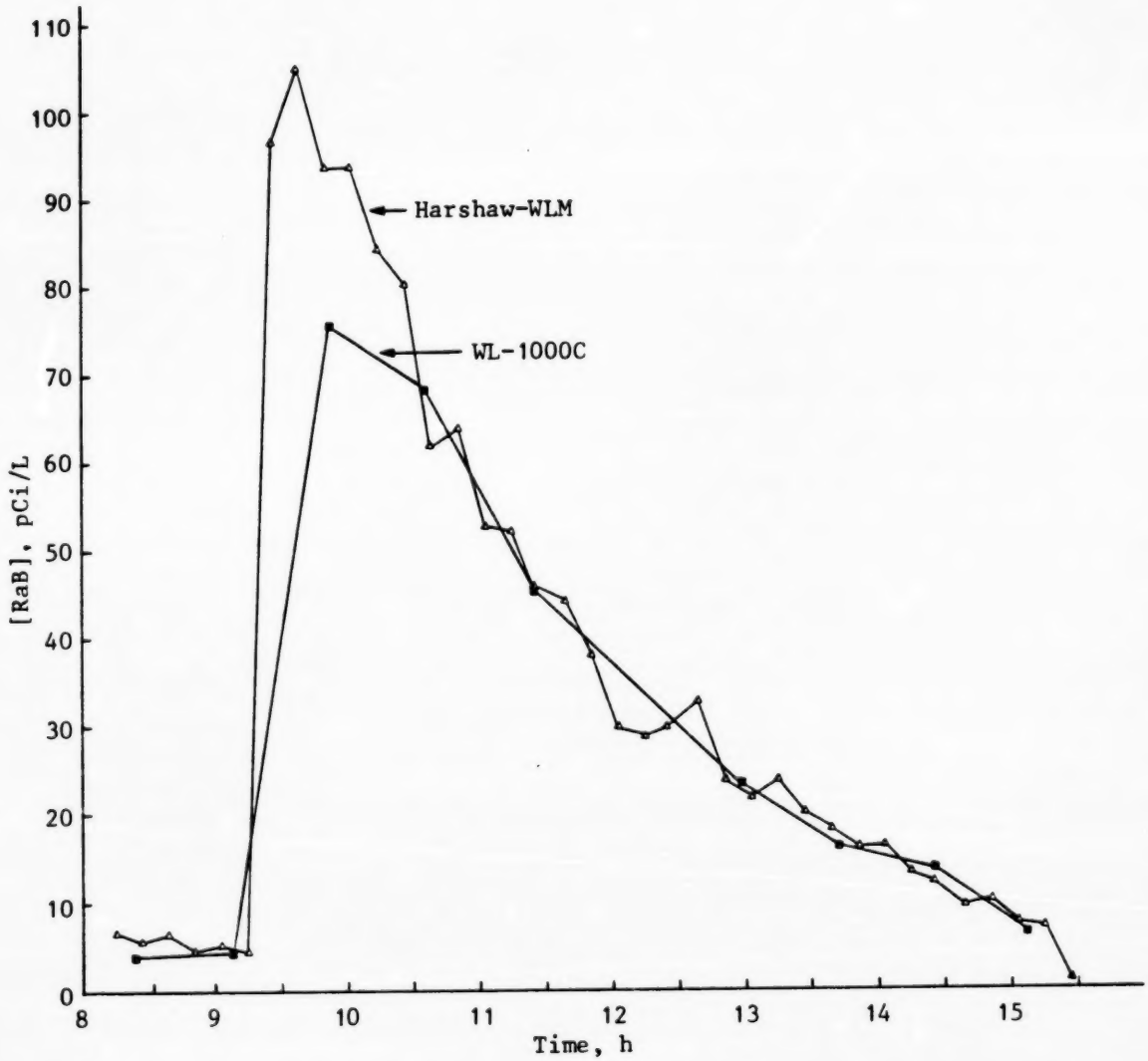

Fig. 4 - RaB concentration versus time for the Harshaw-WLM and the WL-1000C (Rn α-spectroscopy). Experiments were carried out in a radon room.

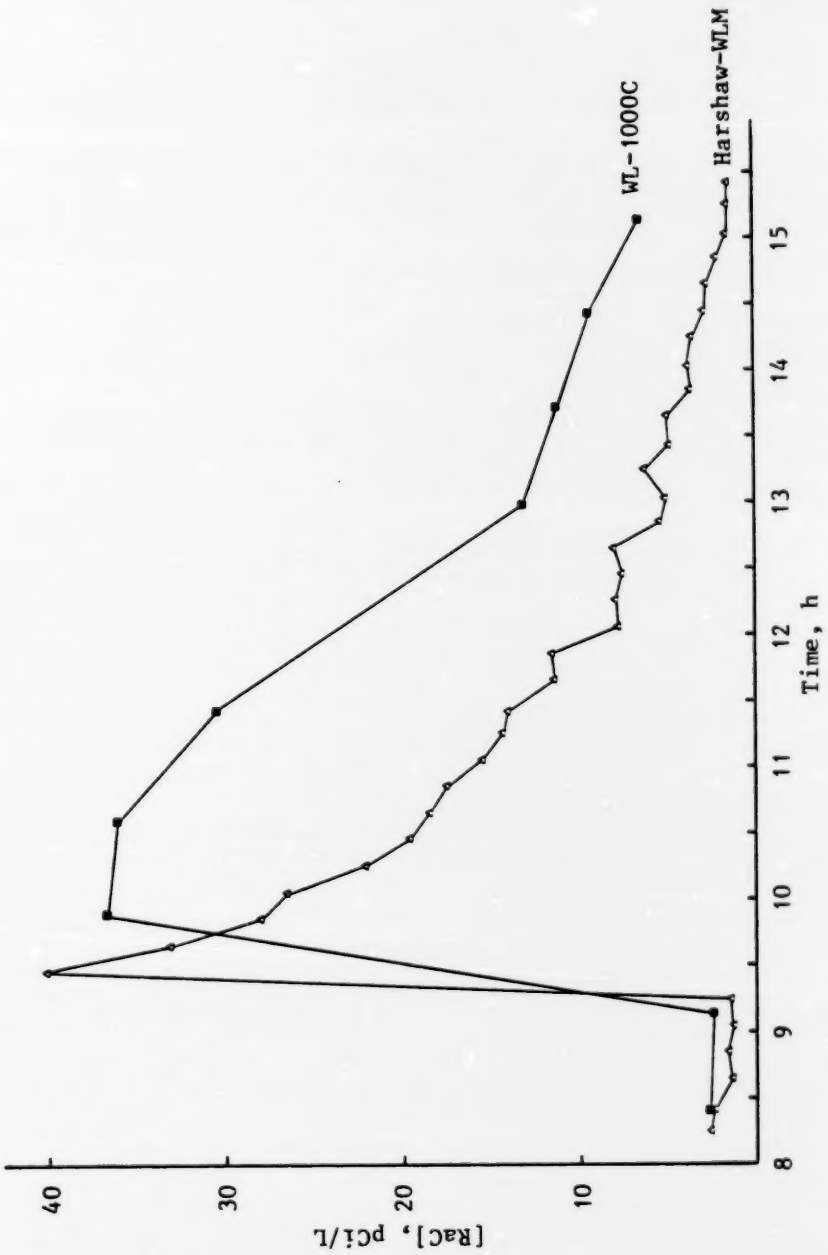

Fig. 5 - RaC concentration versus time for the Harshaw-WLM and the WL-1000C (Rn α-spectroscopy). Measurements were carried out in a radon room.

The disagreement observed between the different instrumentation tested and methods used can be partly ascribed to the rapidly changing radiation conditions of the tests compounded with the different sampling times of the several methods used, and the fact that sampling was not conducted simultaneously with all the instrumentation.

As indicated above, further tests planned in a newly designed, better controlled, large radon room, and in an underground uranium mine could not be carried out. Only measurements in a uranium tailings site were done. As they do not add anything new to the data already presented here, these data will not be discussed here.

CONCLUSIONS

Significant differences were found between the Harshaw-WLM and grab-sampling with conventional non-automated grab-sampling and automated grab-sampling using different methods.

Discrepancies were larger when sampling took place under rapidly changing radiation conditions. This can be partly understood as different methods and instrumentation use different sampling periods, and sampling for all instruments was not conducted simultaneously. Furthermore, the measurement accuracy depends on the method used.

Additional potential sources of error include:

a) Sampling flow rate variation during the sampling period. (Note: except for the grab-sampling instrumentation used, neither of the tested instruments, including the Harshaw-WLM, Pylon WL-1000C and the EDA WLM-300, have sampling flow-rate monitoring capabilities);

b) Air flow leaks in the sampling head depending upon the particular mechanism used to 'hold' the sampling filter to the filter holder;

c) Different sampling flow rates used by different instruments, e.g., ranging from 1 L/min for the EDA WLM-300 to about 30 L/min for the Harshaw-WLM (the Pylon WL-1000C sampled at a rate of about 4 L/min. Grab-sampling was done at about 6 L/min).

It should be indicated that the discussion and conclusions drawn above apply equally well to both the instrumentation under technical evaluation and the grab-sampling methods used to evaluate this instrumentation. Hence, the discrepancies observed do not necessarily reflect any fault of the instruments tested.

SUGGESTIONS FOR IMPROVING THE HARSHAW WLM

Although the analytical procedures and method on which the instrument is based are quite sound, there are a number of improvements and modifications which should be added to the WLM in order to better its reliability and dependability. A few suggestions are given below:

1. The sampling head has been well designed and its plate-out characteristics are most probably excellent, but being located on the top of the instrument it is particularly vulnerable to:
   a) unwanted materials such as dirt, coarse dust, diesel particulates, oil and water mists and the like, all produced during the course of some mining operations and easily falling into the sampling head by gravitational settling. Dirt, dust and other materials are also a cause of concern in milling operations and at tailings sites. Deposition of some of the above unwanted materials may affect the absorptive characteristics of the filtering material to α- and β-particles. It may also contaminate the detectors;
   b) malicious tampering and accidental damage.

2. The Radon Daughter Detector (RGD), Model 101, and the Radiation Computer (RC), Model 100, are connected by a cable which transmits data from the RGD to the RC and which also conveys instructions from the microprocessor in the RC to the RGD to control several vital function operations. This inter-connecting cable runs from the top of the RGD to the top of the RC, therefore impeding closure of the instrument's lids, thereby leaving the instrument totally exposed to the environment.
3. Although the Harshaw-WLM has 'programmable' sampling pump flow-rate and detector efficiency, there is no direct means provided in the instrument for monitoring these variables. We would like to suggest the addition to the instrument of a calibrated rotameter to monitor the sampling flow-rate during sampling. Furthermore, an alpha/beta standard source of such design so as to enable easy positioning of the source between the α- and β-detectors should be provided to enable periodic checking of the detector's efficiency.

We believe items 1 and 2 to be quite a serious drawback which require immediate attention if the instrument is to be used in certain working sites such as the ones indicated above.

At present the instrument operates on techniques developed by Groer et al. (17,22). Some modifications could be introduced in the hardware and software of the instrument to permit measurement of the radon daughter concentration and WL by other methods, including the possibility of counting during sampling. The Harshaw-WLM has no provisions to deal with the presence of thoron decay products, a problem common in some Canadian uranium mines. Some analysis of thoron daughters could be made by running the filter again after the radon daughters have decayed away.

The Harshaw-WLM is somewhat heavy and bulky which makes it difficult

to handle in routine operations. Some design changes could easily be introduced to reduce weight and size.

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